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SPECIAL PUBLICATION ARCCB-SP-88023

INDEX TO BENET LABORATORIES TECHNICAL REPORTS - 1987

R. D. NEIFELD

TECHNICAL PUBLICATIONS AND EDITING SECTION

JUNE 1988

US ARMY ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER
CLOSE COMBAT ARMAMENTS CENTER
BENÉT LABORATORIES
WATERVLIET, N.Y. 12189-4050

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARCCB-SP-88023	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) INDEX TO BENET LABORATORIES TECHNICAL REPORTS - 1987		5. TYPE OF REPORT & PERIOD COVERED Final
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) R. D. Neifeld		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC Benet Laboratories, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS N/A
11. CONTROLLING OFFICE NAME AND ADDRESS US Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000		12. REPORT DATE June 1988
		13. NUMBER OF PAGES 95
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Benet Laboratories
Technical Publications
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Abstracts
Document Control Data

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This is a compilation of technical reports published by Benet Laboratories during 1987.

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UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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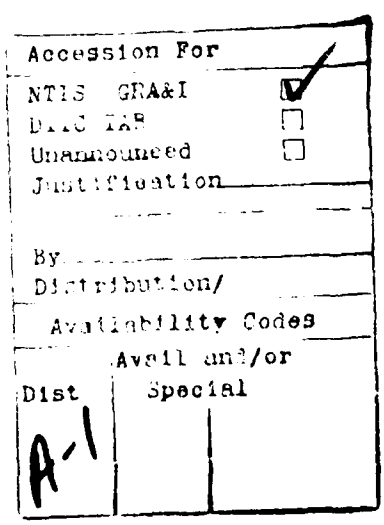
Per Ms. R. D. Neifeld, U. S. Army ARDEC, Benet Labs.



TECHNICAL REPORTS 1987

REPORT NUMBER	TITLE	AUTHOR	DATE
ARCCB-TR-87001	Superconducting Augmented Rail Gun (SARG)	C.G. Homan C.E. Cummings C.M. Fowler	Jan 87
ARCCB-TR-87002	Groove Adhesion Test for Electrodeposited Chromium	S.K. Pan E.S. Chen	Jan 87
ARCCB-TR-87003	Superconducting Augmented Rail Gun (SARG)	C.G. Homan W. Scholz	Feb 87
ARCCB-CR-87004	The Thermal Response of Perforated Muzzle Brakes	MAJ R.E. Dillon, Jr. COL M.A. Paolino M.J. Glennon (Benet POC)	Feb 87
ARCCB-CR-87005	Tank Turret Program	H.J. Reepmeyer R.A. Piacente (Benet POC)	Feb 87
ARCCB-TR-87006	An Evaluation of the Service Failure of Aluminum Nose Cones Using Four Test Techniques	J.A. Kapp R.R. Fujczak R.T. Abbott	Mar 87
ARCCB-TR-87007	Acoustic Emission During Chromium Plating	M.E. Todaro G.P. Capsimalis E.S. Chen	Mar 87
ARCCB-TR-87008	Resonance of Flexural Waves in Gun Tubes	T.E. Simkins	Jul 87
ARCCB-TR-87009	Non-Living Intelligence	M. Johnson R.D. Scanlon	Apr 87
ARCCB-TR-87010	Warm Hydrostatic Extrusion of a Liquid Phase Sintered Tungsten Composite for Kinetic Energy Penetrators - Part I	C.J. Nolan K.J. Tauer	Apr 87
ARCCB-TR-87011	Evaluation of "Never-Seez" Treatment of 120-mm Gun Tube	S.K. Pan L. McNamara G.P. Capsimalis	Apr 87
ARCCB-TR-87012	Variations in the Bainite Hardenability of ASTM A723 Steel	P.J. Cote L.V. Meisel W. Sheldon	May 87

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ARCCB-TR-87013	Experimental and Analytical Investigation of a Steel Pressure Vessel Overwrapped with Graphite Bismaleimide	M.A. Scavullo M.D. Witherell K. Miner T.E. O'Brien W. Yaiser	May 87
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ARCCB-TR-87015	Some Results on Orthotropic High Pressure Cylinders	G.P. O'Hara	Jun 87
ARCCB-TR-87016	An Experimental and Numerical Study of the Flow Through a Vent Hole in a Perforated Muzzle Brake	H.T. Nagamatsu K.Y. Choi R.E. Duffy G.C. Carofano	Jun 87
ARCCB-TR-87017	Fatigue Life Prediction in Thick-Walled Cylinders with Complex Residual Stresses	S.L. Pu P.C.T. Chen	Jul 87
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ARCCB-TR-87020	Stochastic Analysis for Navigation of Autonomous Platforms Using Range Finders	C.N. Shen	Aug 87
ARCCB-TR-87021	The Analysis of Metal Finishing Solutions by Ion Chromatography	S. Sopok	Aug 87
ARCCB-SP-87022	Index to Benet Laboratories Technical Reports - 1986	R.D. Neifeld	Aug 87
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ARCCB-CR-87026	Generic Ammunition Loading System (GALS) - Final Report - Phase II	M.W. Osborne S.J. Kelly R.A. Dahl R.D. Diseth R.C. Schmidt S.C. Reed D. Frandson T. O'Connell D.E. Jones (Benet POC)	Oct 87
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Rensselaer Polytechnic Institute Troy, NY	ARCCB-CR-87032
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SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARCCB-TR-87001	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* SUPERCONDUCTING AUGMENTED RAIL GUN (SARG)		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR*(s)* C. G. Homan, C. E. Cummings, and C. M. Fowler (See Reverse)		8. CONTRACT OR GRANT NUMBER*(s)*
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Armament Research, Develop, & Engr Center Benet Weapons Laboratory, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6111.01.91A0.0 PRON No. 1A6AZ601NMLC
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research, Develop, & Engr Center Close Combat Armaments Center Dover, NJ 07801-5001		12. REPORT DATE January 1987 13. NUMBER OF PAGES 17
14. MONITORING AGENCY NAME & ADDRESS*(if different from Controlling Office)*		15. SECURITY CLASS. *(of this report)* UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

Presented at the Third Symposium on Electromagnetic Launch Technology, Austin, Texas, 22-24 April 1986.
Published in IEEE Transactions on Magnetics.

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Rail Guns
Superconducting Augmentation
Design

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

Superconducting augmentation consists of a superconducting coil operating in the persistent mode closely coupled magnetically with a normally conducting rail gun. A theoretical investigation of the effect of this system on a rail gun has shown that two benefits occur. Projectile velocities increase by more than 50 percent and launch efficiencies increase by more than a factor of two depending on the magnetic coupling between the rail and augmentation circuits.

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7. AUTHORS (Cont'd)

C. E. Cummings and C. M. Fowler
Los Alamos National Laboratory
Los Alamos, NM 87545

20. ABSTRACT (Cont'd)

The previous work evaluated an idealized system by neglecting energy dissipation effects. In this report, we extend the analysis to include the neglected terms and show improved actual launch efficiencies for the SARG configuration.

To evaluate this concept, a one meter, 0.95 cm square bore rail gun powered by a 5 KV, 1440 μf capacitor discharging into a pulse shaping inductance of about 5 μh was constructed. This system will accelerate a 4 g armature type projectile to the 0.8 km/sec range.

Superconducting augmentation will be accomplished using a 4 Tesla dipole magnet recently acquired from DOE's Lawrence Berkeley Laboratory. This magnet system, originally designed as an ESCAR bending magnet, has been modified to a warm bore configuration operating in either the persistent or constant current mode powered by 1600 amp DC supplies. These modifications will allow the above rail gun to be inserted and tested in the SARG configuration.

Several factors, including magnetic quench protection, reproducibility of results, relatively low magnetic coupling coefficients, minimization of rail wear, etc., indicated that this experimental evaluation be conducted with an armature device. An advanced armature design is incorporated in our projectiles.

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARCCB-TR-87002	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) GROOVE ADHESION TEST FOR ELECTRODEPOSITED CHROMIUM		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) S. K. Pan and E. S. Chen		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Armament Research, Develop, & Engr Center Benet Weapons Laboratory, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6111.02.H600.0 PRON No. 1A6DZ602NMSC
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research, Develop, & Engr Center Close Combat Armaments Center Dover, NJ 07801-5001		12. REPORT DATE January 1987 13. NUMBER OF PAGES 16
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for pub'ic release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Presented at the International Conference on Metallurgical Coatings, San Diego, California, 7-11 April 1986.
Published in Proceedings of the Conference.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Adhesion Test
Electrodeposit
Chromium

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A quantitative test has been devised to evaluate the adhesion of electrodeposited chromium on steel substrates. The test involves the cutting of parallel grooves across a plated surface using a small metal shaper equipped with a carbide tool. The grooves are cut at a depth just below the interface and shearing stresses are generated which can produce failure of the coating. In general, varying amounts of residual chromium are left on the surface of the

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20. ABSTRACT (CONT'D)

lands depending on the relative cohesive and adhesive bond strengths of the electrodeposited chromium. Energy dispersive x-ray analysis is used to map the distribution of residual chromium and obtain an intensity count. The ratio of intensity count normalized against a reference of 100 percent chromium coverage provides a quantitative measurement of adhesion. The groove adhesion test was found to be equally applicable for the evaluation of both hard chromium and soft chromium deposits.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARCCB-TR-87003	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) SUPERCONDUCTING AUGMENTED RAIL GUN (SARG)		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Clarke G. Homan and Wilfred Scholz (See Reverse)		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Armament Research, Develop, & Engr Center Benet Weapons Laboratory, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6111.01.91A0.0 PRON No. 1A6AZ601NMLC
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research, Develop, & Engr Center Close Combat Armaments Center Dover, NJ 07801-5001		12. REPORT DATE February 1987 13. NUMBER OF PAGES 16
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Presented at the U.S. Army Science Conference, U.S. Military Academy, West Point, NY, 17-20 June 1986.
Published in Proceedings of the Conference.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Rail Gun
Superconducting Augmentation
Theoretical Analysis

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Both the energy efficiency and projectile velocity of a rail gun system can be substantially increased by the addition of an adjunct superconducting augmentation coil system. The energy efficiency results from the superconducting coil's ability to recover the rail magnetic field energy normally dissipated at the end of launch in rail guns, by means of a unique application of the flux conservation property of superconducting coils. The increased velocity results
(Cont'd on Reverse)

7. AUTHORS (CONT'D)

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Albany, NY

20. ABSTRACT (CONT'D)

from the augmented Lorentz force due to the augmentation coil magnetic field. In an idealized system, both the energy efficiency and projectile velocities can be increased by more than 80 percent, dependent on the magnetic coupling between the rail and augmentation coils. The theoretical evaluation has been extended to include dissipative effects which reveal that actual launch efficiencies are increased from 25 percent (rail gun) to over 50 percent (SARG). A theoretical analysis of SARG is presented here together with the progress of an experimental demonstrator developed at Benet Weapons Laboratory.

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARCCB-CR-87004	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) THE THERMAL RESPONSE OF PERFORATED MUZZLE BRAKES		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) MAJ Robert E. Dillon, Jr. and COL Michael A. Paolino		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Military Academy Department of Mechanics West Point, NY 10996-1792		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research, Develop, & Engr Center Close Combat Armaments Center Dover, NJ 07801-5001		12. REPORT DATE February 1987 13. NUMBER OF PAGES 25
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) US Army Armament Research, Develop, & Engr Center Benet Weapons Laboratory, SMCAR-CCB-TL Watervliet, NY 12189-4050		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Distribution limited to Department of Defense only because of critical technology; February 1987. Other requests for this document must be referred to Commander, US Army Armament Research, Development, and Engineering Center, ATTN: Benet Weapons Laboratory, SMCAR-CCB-DA, Watervliet, NY 12189-4050.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Michael J. Glennon - Benet Weapons Laboratory Project Engineer

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Perforated Muzzle Brakes
Convection
Conduction
Radiation
Heat Transfer
Control Volume
Blowdown

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A computer program was developed to study the heat transfer in perforated muzzle brakes. The numerical procedure used in this study divided the muzzle into a finite difference grid with suitably arranged node points. The control volume approach was used to develop finite difference node equations to model the heat input to the muzzle from the hot propellant gases.

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20. ABSTRACT (CONT'D)

The computer program was tested by comparing numerical results with experimental data. The numerical results and experimental data are in good agreement. The thermal response of the muzzle is presented as time histories of the inside and outside tube wall temperatures. A comparison is made of a conventional solid muzzle and an axisymmetric perforated muzzle. The gun modeled is the 105mm M68 tank cannon. The temperature histories of both muzzle configurations are compared for a "worst case" firing scenario of eight rounds of M735 APFSDS ammunition with a five second delay between rounds. Computations are carried out to 90 seconds at which time the muzzle temperature has stabilized. Results of this study show that the perforations increase the temperature of the muzzle by 22% over that of the standard, solid muzzle.

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: ARCCB-CR-87005	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): TANK TURRET PROGRAM	5. TYPE OF REPORT & PERIOD COVERED: Final Report, January 1986 - November 1986
6. PERFORMING ORG. REPORT NUMBER	
7. AUTHOR(s): Herman J. Reepmeyer	8. CONTRACT OR GRANT NUMBER(s): DAAA22-86-M-0055
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Herman J. Reepmeyer, Proprietor, R.D. #1, Box 53, Cohoes, NY 12047	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: AMCMS No. 6940.OR.2200
11. CONTROLLING OFFICE NAME AND ADDRESS: US Army Armament Research, Develop, & Engr Center, Close Combat Armaments Center, Dover, NJ 07801-5001	12. REPORT DATE: February 1987
	13. NUMBER OF PAGES: 5
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office): US Army Armament Research, Develop, & Engr Center, Benet Weapons Laboratory, SMCAR-CCB-TL, Watervliet, NY 12189-4050	15. SECURITY CLASS. (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Distribution limited to US Government Agencies only because of administrative/ operational use; February 1987. Other requests for this document must be referred to Commander, US Army Armament Research, Development, and Engineering Center, ATTN: Benet Weapons Laboratory, SMCAR-CCB-DC, Watervliet, New York 12189-4050.

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18. SUPPLEMENTARY NOTES

Robert A. Piacente - Benet Weapons Laboratory Project Engineer

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Requests for Waivers/Deviations
Engineering Change Proposals
Technical Data Packages
Miscellaneous Tasks

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report is a compilation of work assigned to and accomplished by Northern Industrial Services, Inc., on Contract DAAA22-86-C-0117. It also includes a record of the funds expended and acceptance level of work accomplished on the aforementioned contract.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARCCB-TR-87006	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* AN EVALUATION OF THE SERVICE FAILURE OF ALUMINUM NOSE CONES USING FOUR TEST TECHNIQUES		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) J. A. Kapp, R. R. Fujczak, and R. T. Abbott		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Armament Research, Develop, & Engr Center Benet Weapons Laboratory, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 4111.16.2935.6 PRON No. 1A42RZSXNMLC
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research, Develop, & Engr Center Close Combat Armaments Center Dover, NJ 07801-5001		12. REPORT DATE March 1987 13. NUMBER OF PAGES 18
14. MONITORING AGENCY NAME & ADDRESS*(if different from Controlling Office)*		15. SECURITY CLASS. *(of this report)* UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

Presented at the 1986 Spring Conference of the Society for Experimental Mechanics (SEM), New Orleans, LA, 9-13 June 1986.
Published in Proceedings of the Conference.

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Residual Stresses	J-Integral
Fracture Toughness	Ultrasonics
Simulation Tests	Hole Drilling Technique

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

Service failure of 7075-T6 aluminum nose cones was evaluated by four techniques:

1. Residual stress measurements (hole drilling technique).
2. Notched crack initiation toughness tests.
3. Verification of fracture toughness.
4. Simulation tests of finished nose cones.

In this examination, residual stress differences contributed most to the failure analysis.

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: ARCCB-TR-87007
2. GOVT ACCESSION NO.:
3. RECIPIENT'S CATALOG NUMBER:

4. TITLE (and Subtitle): ACOUSTIC EMISSION DURING CHROMIUM PLATING
5. TYPE OF REPORT & PERIOD COVERED: Final
6. PERFORMING ORG. REPORT NUMBER:

7. AUTHOR(s): M. E. Todaro, G. P. Capsimalis, and E. S. Chen

8. CONTRACT OR GRANT NUMBER(s):

9. PERFORMING ORGANIZATION NAME AND ADDRESS:
US Army Armament Research, Develop, & Engr Center
Benet Weapons Laboratory, SMCAR-CCB-TL
Watervliet, NY 12189-4050

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS:
AMCMS No. 6920.00.0770.011
PRON No. 1A62ZH7DNMSC

11. CONTROLLING OFFICE NAME AND ADDRESS:
US Army Armament Research, Develop, & Engr Center
Close Combat Armaments Center
Dover, NJ 07801-5001

12. REPORT DATE: March 1987
13. NUMBER OF PAGES: 18

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office):

15. SECURITY CLASS. (of this report): UNCLASSIFIED
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Presented at the International Conference on Metallurgical Coatings, San Diego, California, 7-11 April 1986.
Published in Proceedings of the Conference.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Acoustic Emission
Chromium
Electrodeposition
Plating

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The authors used acoustic emission to study crack formation during the electrodeposition of chromium over a range of temperatures and current densities which characterize the transition from high contraction (HC) to low contraction (LC) chromium. Several characteristics of the acoustic emissions were examined, including the amplitude distribution, signal energy, emission rate, count rate, and frequency spectrum. The acoustic emission technique

(CONT'D ON REVERSE)

20. ABSTRACT (CONT'D)

detected the onset of cracking and yielded useful information regarding the number of cracks. Such information acquired during the actual deposition process can be an invaluable aid in determining the quality of the deposit and in developing improved chromium coatings.

Experimental data were acquired and analyzed using commercial acoustic emission instrumentation, including standard piezoelectric transducers. The deposition bath was a standard aqueous solution of 250 g/l chromic acid and 2.5 g/l sulfuric acid. The solution temperature and deposition current density were varied to obtain deposits of differing crack content. The substrate was electropolished carbon steel.

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: ARCCB-TR-87008	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): RESONANCE OF FLEXURAL WAVES IN GUN TUBES	5. TYPE OF REPORT & PERIOD COVERED: Final
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Thomas E. Simkins	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: US Army Armament Research, Develop, & Engr Center Benet Weapons Laboratory, SMCAR-CCB-TL Watervliet, NY 12189-4050	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: AMCMS No. 6111.02.H610.0 PRON No. 1A7AZ703NMSC
11. CONTROLLING OFFICE NAME AND ADDRESS: US Army Armament Research, Develop, & Engr Center Close Combat Armaments Center Dover, NJ 07801-5001	12. REPORT DATE: July 1987 13. NUMBER OF PAGES: 43
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Distribution limited to US Government Agencies only because of test and evaluation; July 1987. Other requests for this document must be referred to Commander, US Army Armament Research, Development, and Engineering Center, ATTN: Benet Weapons Laboratory, SMCAR-CCB-RA, Watervliet, New York 12189-4050.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Axially Symmetric Stress Waves in Cylinders
Axially Symmetric Motion of Cylinders
Axially Symmetric Motion of Cylindrical Shells
Flexural Vibrations in Tubes/Cylinders
Resonance
Flexural Waves
Moving Pressure

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Unusually large dynamic strains have been measured on the surface of a 120-mm gun tube. The primary cause of these strains, which oscillate at approximately 15 khz, is a resonance of axially symmetric flexural vibrations travelling in a wave-like fashion with the moving ballistic pressure. Theoretical strain predictions, based on the work of Mirsky and Herrmann, are in excellent agreement with the measured values.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARCCB-TR-87009	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* NON-LIVING INTELLIGENCE		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Mark Johnson and Raymond D. Scanlon		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Armament Research, Develop, & Engr Center Benet Weapons Laboratory, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6111.01.91A0.0 PRON No. 1A6AZ601NMLC
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research, Develop, & Engr Center Close Combat Armaments Center Dover, NJ 07801-5001		12. REPORT DATE April 1987 13. NUMBER OF PAGES 13
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

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17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Non-Living Intelligence
NLI
Neural Modeling
Connectionism
Brain

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

The science of constructing machines that think using the brain as a model is called non-living intelligence (NLI). This report investigates the origins of NLI and discusses recent progress in the field.

A computer simulation has been developed which exhibits the behavior of a primitive organism capable of adapting and surviving. The program is used to demonstrate learning using the hypothesis of synaptic plasticity. A neural

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20. ABSTRACT (CONT'D)

network consisting entirely of sensory and motor neurons models the reward mechanism of the vertebrate brain.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARCCB-TR-87010	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) WARM HYDROSTATIC EXTRUSION OF A LIQUID PHASE SINTERED TUNGSTEN COMPOSITE FOR KINETIC ENERGY PENETRATORS - PART I		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Charles J. Nolan and Kenneth J. Tauer (See reverse)		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Armament Research, Develop, & Engr Center Benet Weapons Laboratory, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6126.23.1BL0.0 PRON No. 1A-7-7Z76A-NMSC
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research, Develop, & Engr Center Close Combat Armaments Center Dover, NJ 07801-5001		12. REPORT DATE April 1987 13. NUMBER OF PAGES 22
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Liquid Phase Sintering
Tungsten Alloy Composite
Warm Hydrostatic Extrusion
Interfacial Porosity
Strengthening Mechanisms

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Kinetic energy penetrator material was produced by warm hydrostatic extrusion of billets which had been fabricated by liquid phase sintering a 90W-7Ni-3Fe jacket to a pure tungsten core. Both components of the billets extruded with no external cracking and only isolated internal cracking. An excellent metallurgical bond was obtained between the core and jacket material when porosity, which developed during the sintering cycle, was absent. The large deformation produced by the warm hydrostatic extrusion resulted in significant strain-hardening of the jacket and core materials.

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7. AUTHORS (CONT'D)

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Materials Technology Laboratory
Watertown, MA

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARCCB-TR-87011	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* EVALUATION OF "NEVER-SEEZ" TREATMENT OF 120 MM GUN TUBE		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) S. K. Pan, L. McNamara, and G. P. Capsimalis		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Armament Research, Develop, & Engr Center Benet Weapons Laboratory, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6126.23.1BL0.0 PRON No. 1A-7-7Z76A-NMSC
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research, Develop, & Engr Center Close Combat Armaments Center Dover, NJ 07801-5001		12. REPORT DATE April 1987 13. NUMBER OF PAGES 51
14. MONITORING AGENCY NAME & ADDRESS*(if different from Controlling Office)*		15. SECURITY CLASS. *(of this report)* UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Distribution limited to US Government Agencies only because of test and evaluation; April 1987. Other requests for this document must be referred to Commander, US Army Armament Research, Development, and Engineering Center, ATTN: Benet Weapons Laboratory, SMCAR-CCB-RP, Watervliet, New York 12189-4050.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Never-Seez	Scanning Electron Microscopy
Additive Agent Evaluation	120 mm M256 Gun Tube
Energy Dispersive X-Ray Analysis	Chromium Coating

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

Scanning electron microscopy (SEM) and energy dispersive x-ray analysis (EDAX) were employed after proof firing to evaluate the protective effects of "Never-Seez" treatment on chromium coated gun tubes. A chromium coated 120 mm M256 gun was selected for the experimental study. A tape replicating non-destructive method was used for the extraction and detection of "Never-Seez" particles possibly trapped in the cracks of the chromium coating. The results from this

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20. ABSTRACT (CONT'D)

method did not support the presence of "Never Seez" in the cracks. Four post-firing samples obtained via the sectioning method provided no significant evidence of "Never-Seez" particles on the bore surface or in the cross-section.

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARCCB-TR-87012	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* VARIATIONS IN THE BAINITE HARDENABILITY OF ASTM A723 STEEL		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Paul J. Cote, Lawrence V. Meisel, and William Sheldon (see reverse)		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Armament Research, Develop, & Engr Center Benet Weapons Laboratory, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6111.02.H600.0 PRON No. 1A6DZ602NMSC
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research, Develop, & Engr Center Close Combat Armaments Center Dover, NJ 07801-5001		12. REPORT DATE May 1987 13. NUMBER OF PAGES 15
14. MONITORING AGENCY NAME & ADDRESS*(if different from Controlling Office)*		15. SECURITY CLASS. *(of this report)* UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

Presented at the ASME 1986 Pressure Vessel and Piping Conference, Chicago, IL, 21-25 July 1986.
Published in Proceedings of the Conference.

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Hardenability
Bainite
Austenite
Steel

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

Austenite transformation characteristics were determined for ASTM A723 steels prepared by various suppliers and refining methods. Standard measurement techniques as well as differential thermal analysis and thermomagnetic analysis were employed.

Remarkably large variations in hardenability are found among these steels; the variations appear to be due to differences of less than one percent in the
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7. AUTHORS (CONT'D)

William Sheldon
Operations Directorate
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Watervliet, NY 12189-4050

20. ABSTRACT (CONT'D)

nickel content among the samples. These hardenability properties are shown to correlate in a straightforward way with mechanical properties of large size components that were quenched at different rates.

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: ARCCB-TR-87013	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): EXPERIMENTAL AND ANALYTICAL INVESTIGATION OF A STEEL PRESSURE VESSEL OVERWRAPPED WITH GRAPHITE BISMALEIMIDE	5. TYPE OF REPORT & PERIOD COVERED: Final
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): M. A. Scavullo, M. D. Witherell, K. Miner, T. E. O'Brien, and W. Yaiser	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: US Army ARDEC, Benet Weapons Laboratory, SMCAR-CCB-TL, Watervliet, NY 12189-4050	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: AMCMS No. 2437353410012, PRON No. 1A62ZH3HNMSC
11. CONTROLLING OFFICE NAME AND ADDRESS: US Army ARDEC, Close Combat Armaments Center, Picatinny Arsenal, NJ 07806-5000	12. REPORT DATE: May 1987
	13. NUMBER OF PAGES: 25
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	15. SECURITY CLASS. (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Finite Element Stress Analysis
ABAQUS
Composite Cylinder
Graphite-Bismaleimide

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In this report we present the results of an analytical (finite element) and experimental investigation of the stress-strain response of a composite cylinder subjected to an internal pressurization cycle. The composite cylinder is constructed of a steel liner and a graphite-bismaleimide outer shell. Results are also presented for cases where the structure was subjected to a temperature cycle above the manufacturer's specified operating temperature.

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20. ABSTRACT (CONT'D)

The results indicate a delayed strain response in the composite outer shell and only small changes in burst pressure and strain-to-failure for temperature cycles up to 200°F higher than the manufacturer's specified temperatures.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARCCB-TR-87014	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* TEST METHODS FOR MATERIAL CHARACTERIZATION OF COMPOSITE CYLINDERS		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR*(s)* Y. F. Cheng		8. CONTRACT OR GRANT NUMBER*(s)*
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC Benet Weapons Laboratory, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6126.23.1BL0.0 PRON No. 1A-7-7Z76A-NMSC
11. CONTROLLING OFFICE NAME AND ADDRESS US Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000		12. REPORT DATE June 1987 13. NUMBER OF PAGES 7
14. MONITORING AGENCY NAME & ADDRESS*(if different from Controlling Office)*		15. SECURITY CLASS. *(of this report)* UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

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17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Composite Cylinder	Material Characterization
Elastics Constants	Anisotropic Materials
Stiffness Matrix	Orthotropic Materials
Compliance Matrix	Transversely Isotropic Materials

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

A study has been conducted of test methods for material characterization of composite cylinders. The purpose was to obtain constants in the stiffness matrix C_{ij}, which is necessary in the designing process. Test methods for determining engineering constants (Young's moduli, Poisson's ratios, and shear moduli) for composite cylinders with fibers in the axial and circumferential directions have been found. Constants in the compliance matrix S_{ij} can then

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20. ABSTRACT (CONT'D)

be calculated by means of the well-known equations relating compliance matrix to engineering constants. Finally, the stiffness matrix C_{ij} is given by the inverse of S_{ij}. For composite cylinders with other fiber directions, engineering constants may be obtained by the rotation of coordinate axes and rule of mixture.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARCCB-TR-87015	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) SOME RESULTS ON ORTHOTROPIC HIGH PRESSURE CYLINDERS		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) G. Peter O'Hara		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC Benet Weapons Laboratory, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6920.0R.8970.021 PRON No. 1A62ZHFCNMLC
11. CONTROLLING OFFICE NAME AND ADDRESS US Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000		12. REPORT DATE June 1987 13. NUMBER OF PAGES 25
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Cylinder
Stress
Strain
Composite

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

With the current emphasis on composite materials, it has become necessary to use the thick-wall cylinder equations for cylindrically orthotropic materials. This report is a preliminary investigation of these equations. The most important result is that many of the old ideas of high pressure cylinders will have to be changed. When the cylinder is very thin (wall ratio near 1.0), the simple thin-wall equations are adequate. However, as the thickness increases, stress variation through the wall becomes large and the full thick-wall
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20. ABSTRACT (CONT'D)

solution is necessary. In orthotropic (composite) cylinders this transition happens at a lower wall ratio. Furthermore, the maximum useful wall ratio may become smaller for a composite cylinder.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARCCB-TR-87016	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) AN EXPERIMENTAL AND NUMERICAL STUDY OF THE FLOW THROUGH A VENT HOLE IN A PERFORATED MUZZLE BRAKE		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) H. T. Nagamatsu, K. Y. Choi, R. E. Duffy, and G. C. Carofano (see reverse)		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC Benet Weapons Laboratory, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6111.02.H600.0 PRON No. 1A6DZ602NMSC
11. CONTROLLING OFFICE NAME AND ADDRESS US Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000		12. REPORT DATE June 1987 13. NUMBER OF PAGES 25
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Distribution limited to US Government Agencies and their contractors only because of critical technology; June 1987. Other requests for this document must be referred to Commander, US Army Armament Research, Development, and Engineering Center, ATTN: Benet Weapons Laboratory, SMCAR-CCB-RA, Watervliet, NY 12189-4050.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Three-Dimensional Flow
Inviscid Flow
Shock Tube Flow
Muzzle Brake Flow
Perforated Muzzle Brake

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A perforated muzzle brake consists simply of a set of vent holes drilled through the wall of a cannon near the muzzle. When the propellant gas expands through this configuration, an asymmetric pressure distribution develops in each hole with the highest pressures acting on the downstream surface. To calculate that resulting braking force, a detailed knowledge of the pressure distribution is required. This was determined experimentally and numerically using a three-dimensional code. The predicted mass and momentum fluxes from
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7. AUTHORS (Cont'd)

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20. ABSTRACT (Cont'd)

the hole were averaged and used in a one-dimensional flow model with mass extraction at the tube wall to predict the performance of an entire brake. Comparison with the experimental data of Dillon shows favorable agreement.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARCCB-TR-87017	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) FATIGUE LIFE PREDICTION IN THICK-WALLED CYLINDERS WITH COMPLEX RESIDUAL STRESSES		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) S. L. Pu and P. C. T. Chen		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC Benet Weapons Laboratory, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6111.02.H600.0 PRON No. 1A6DZ602NMSC
11. CONTROLLING OFFICE NAME AND ADDRESS US Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000		12. REPORT DATE July 1987 13. NUMBER OF PAGES 20
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Presented at ASTM National Symposium on Analytical and Experimental Methods for Residual Stress Effects in Fatigue, Phoenix, AZ, 20-21 October 1986. Published in Proceedings of the Symposium.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Fatigue Life	Stress-Intensity Range
Radial Crack	Shape Factors
Thick-Walled Cylinder	Negative K-Factor

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The large variation in stress intensity factors corresponding to various material models for a single, radial, straight-fronted crack in a pressurized, partially autofrettaged cylinder leads to a drastic difference in the fatigue life predictions. None of the predicted lives agree with experimental results. Possible explanations of the discrepancy are given and corresponding correction factors are introduced. The predicted lives based on the corrected stress intensity ranges are reasonably close to a set of well-documented experimental results of Throop and Fujczak.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARCCB-TR-87018	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) ANALYSIS OF COMPOSITE SHRINK FITS - TRESCA MATERIAL		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Peter C. T. Chen		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC Benet Weapons Laboratory, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6111.02.H600.0 PRON No. 1A6DZ602NMSC
11. CONTROLLING OFFICE NAME AND ADDRESS US Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000		12. REPORT DATE July 1987 13. NUMBER OF PAGES 21
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Presented at the Fourth Army Conference on Applied Mathematics and Computing, Cornell University, Ithaca, New York, 27-30 May 1986.
Published in Proceedings of the Conference.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Shrink Fits
Plastic Deformation
Tresca's Yield Condition
Flow Rule
Plane Stress

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A thin composite shrink fit assembly is examined herein using an elastic-plastic analysis. The ring and disk are made of different materials. Interferences large enough to induce plastic deformations in the ring are considered. The ring material is assumed to be a linear strain-hardening material that obeys Tresca's yield condition and the associated flow rule. The explicit expressions for stresses and deformations in the shrink fit assembly have been

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20. ABSTRACT (CONT'D)

obtained. Numerical results are presented for shrink fit assemblies with different geometric ratio, hardening parameter, and different combinations of materials.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARCCB-TR-87019	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* THE C^2 CONTINUITY OF PIECEWISE CUBIC HERMITE POLYNOMIALS WITH UNEQUAL INTERVALS		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) C. N. Shen		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC Benet Weapons Laboratory, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6111.01.91A0.0 PRON No. 1A6AZ601NMLC
11. CONTROLLING OFFICE NAME AND ADDRESS US Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000		12. REPORT DATE July 1987 13. NUMBER OF PAGES 12
14. MONITORING AGENCY NAME & ADDRESS*(if different from Controlling Office)*		15. SECURITY CLASS. *(of this report)* UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

Presented at the Fourth Army Conference on Applied Mathematics and Computing, Cornell University, Ithaca, New York, 27-30 May 1986.
Published in Proceedings of the Conference.

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Hermite Polynomials
Spline Functions
Data Smoothing
Laser Vision System

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

Cubic hermite polynomials are usually C^2 continuous. With the introduction of smoothing within the intervals, the second derivatives can be made continuous. This may be applied to the autonomous vehicle problem with unequal laser scanning.

In using a laser range finder to measure the range, the direction of these laser rays can be subjected to angular errors. These errors, in the direction
(CONT'D ON REVERSE)

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20. ABSTRACT (CONT'D)

of the elevation angle, affect the determination of in-path slopes for navigation of autonomous vehicles. A nonuniform grid may be employed to compute by the spline function method with cubic hermite polynomials. For the purpose of smoothing, it is essential to obtain continuous second derivatives at the grid point from both sides.

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: ARCCB-TR-87020	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): STOCHASTIC ANALYSIS FOR NAVIGATION OF AUTONOMOUS PLATFORMS USING RANGE FINDERS	5. TYPE OF REPORT & PERIOD COVERED: Final
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): C. N. Shen	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: US Army ARDEC Benet Weapons Laboratory, SMCAR-CCB-TL Watervliet, NY 12189-4050	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: AMCMS No. 6111.01.91A0.0 PRON No. 1A6AZ601NMLC
11. CONTROLLING OFFICE NAME AND ADDRESS: US Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000	12. REPORT DATE: August 1987 13. NUMBER OF PAGES: 14
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	15. SECURITY CLASS. (of this report): UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Presented at the Workshop on Automation and Robotics for Military Applications, Huntsville, AL, 22-23 October 1986.
Published in Proceedings of the Workshop.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Laser Range Finder
Spline Functions
Vision Systems
Autonomous Vehicle

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

For range finders having noncooperative targets and considerable measurement errors, a stochastic analysis is necessary to determine the differentials such as the gradient of a terrain during navigation of an autonomous platform. The angular measurement errors in elevation or azimuth contribute a deteriorated effect of the gradient estimate, especially when the terrain or target is far away. The smoothing of these gradients can be obtained by using an optimization method for approximation involving spline functions. This method
(CONT'D ON REVERSE)

20. ABSTRACT (CONT'D)

can be applied to solve the following problems: whether the platform can climb on the estimated in-path slope or whether it will tip over on the estimated cross-path.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARCCB-TR-87021	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) THE ANALYSIS OF METAL FINISHING SOLUTIONS BY ION CHROMATOGRAPHY		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Samuel Sopok		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC Benet Laboratories, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6126.23.1BL0.0 PRON No. A172Z76AA11A
11. CONTROLLING OFFICE NAME AND ADDRESS US Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000		12. REPORT DATE August 1987 13. NUMBER OF PAGES 216
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

This was a thesis in partial fulfillment of the requirements for degree of Doctor of Philosophy in Chemistry at Rensselaer Polytechnic Institute, Troy, New York.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Ion Chromatography
Metal Finishing
Chromium Plating

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Ion chromatography is very effective for ionic and polar species determinations. Separation of the analytes into pure peaks simplifies detection compared to detecting the same species in the unseparated sample matrix. One of the methods provides important improvements on existing methods, while the rest provide new and improved ways to analyze metal finishing solutions. The advantages of these methods are that considerable improvements were made in

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20. ABSTRACT (CONT'D)

the areas of: trace ion determinations in the presence of other extremely high ionic concentrations, analysis time, analyst intervention, sensitivity, automation, and multi-ion determinations while maintaining equal precision and specificity compared to traditional chemical methods now in use.

This report describes procedures for the analysis of solutions for chromium plating, acid finishing, metal cyanide plating, and their associated waste solutions. These metal finishing solutions are very successfully analyzed by ion chromatography using a diverse range of techniques.

For the above matrices, the following is a brief summary of the automated procedures developed: analysis of chromium, iron, and copper aqua-complexes using atomic absorption or visible detection; analysis of iron and copper cyano-complexes using atomic absorption or conductivity detection; and analysis of chromate, sulfate, oxalate, phosphate, nitrate, nitrite, formate, and glycolate by conductivity detection. Atomic absorption detection is the laboratory method of choice for metals, while visible and conductivity detection are universally suitable.

An extensive study was made on the influence of injected samples affecting eluent equilibria and thus detection. It is shown that in order to achieve reliable results, samples and standards must have similar acid-base characteristics.

These methods are an improvement to standard methods now in practice and have been tested for three years on real industrial samples with excellent results.

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARCCB-SP-87022	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* INDEX TO BENET LABORATORIES TECHNICAL REPORTS - 1986		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) R. D. Neifeld		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC Benet Laboratories, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS N/A
11. CONTROLLING OFFICE NAME AND ADDRESS US Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000		12. REPORT DATE August 1987 13. NUMBER OF PAGES 103
14. MONITORING AGENCY NAME & ADDRESS*(if different from Controlling Office)*		15. SECURITY CLASS. *(of this report)* UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Benet Laboratories
Technical Publications
Bibliography
Abstracts
Document Control Data

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

This is a compilation of technical reports published by Benet Laboratories during 1986.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARCCB-SP-87023	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) PROCEEDINGS OF THE FIFTH U.S. ARMY SYMPOSIUM ON GUN DYNAMICS		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Editors: Dr. Thomas E. Simkins Clarke G. Homan		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC Benet Laboratories, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS N/A
11. CONTROLLING OFFICE NAME AND ADDRESS US Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000		12. REPORT DATE September 1987 13. NUMBER OF PAGES 375
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Presented at the Fifth U.S. Army Symposium on Gun Dynamics, The Institute on Man and Science, Rensselaerville, New York, 23-25 September 1987.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Acquisition	Electromagnetic Propulsion
Ballistics	Precision
Barrel Vibration	Stabilization
Dynamics	Target Acquisition

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This represents a compilation of technical papers concerning analyses, design, measurement, and automation of gun dynamics. The authors represent a cross-section of the scientific and technical community, including universities, industrial, and Government research laboratories.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARCCB-TR-87024	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* ADAPTIVE FINITE ELEMENT METHODS FOR PARABOLIC SYSTEMS IN ONE- AND TWO-SPACE DIMENSIONS		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Slimane Adjerid and Joseph E. Flaherty (CONT'D ON REVERSE)		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC Benet Weapons Laboratory, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6111.02.H600.0 PRON No. 1A6DZ602NMSC
11. CONTROLLING OFFICE NAME AND ADDRESS US Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000		12. REPORT DATE September 1987 13. NUMBER OF PAGES 32
14. MONITORING AGENCY NAME & ADDRESS*(if different from Controlling Office)*		15. SECURITY CLASS. *(of this report)* UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

Presented at the Fourth Army Conference on Applied Mathematics and Computing, Cornell University, Ithaca, New York, 27-30 May 1986.
Published in the Proceedings of the Conference.
(CONT'D ON REVERSE)

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Adaptive Methods
Finite Element Methods
Parabolic Partial Differential Equations
Local Mesh Pefinement
Mesh Moving Techniques
Method of Lines

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

We discuss adaptive finite element methods for solving initial-boundary value problems for vector systems of parabolic partial differential equations in one- and two-space dimensions.

One-dimensional systems are discretized using piecewise linear finite element approximations in space and a backward difference code for stiff ordinary differential systems in time. A spatial error estimate is calculated using
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SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

7. AUTHORS (CONT'D)

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18. SUPPLEMENTARY NOTES (CONT'D)

This research was partially supported by the U.S. Air Force Office of Scientific Research, Air Force Systems Command, USAF, under Grant Number AFOSR 85-0156 and the U.S. Army Research Office under Contract Number DAAL 03-86-K-0112. This work was used to partially fulfill the Ph.D. requirements of the first author at the Rensselaer Polytechnic Institute.

20. ABSTRACT (CONT'D)

piecewise quadratic approximations that employ nodal superconvergence to increase computational efficiency. This error estimate is used to move and refine the finite element mesh in order to equidistribute a measure of the total spatial error and to satisfy a prescribed error tolerance. Ordinary differential equations for the spatial error estimate and the mesh motion are integrated in time using the same backward difference software that is used to determine the finite element solution.

Two-dimensional systems are discretized using piecewise bilinear finite element approximations in space and backward difference software in time. A spatial error estimate is calculated using piecewise cubic approximations that take advantage of nodal superconvergence. This error estimate is used to locally refine a stationary finite element mesh in order to satisfy a prescribed spatial error tolerance.

Some examples are presented in order to illustrate the effectiveness of our error estimation technique and the performance of our adaptive algorithm.

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: ARCCB-CR-87025	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE *(and Subtitle)*: FINAL REPORT GENERIC AMMUNITION LOADING SYSTEM (GALS) PHASE II	5. TYPE OF REPORT & PERIOD COVERED: Final Report - Phase II May 1986 - April 1987
	6. PERFORMING ORG. REPORT NUMBER: 0588d
7. AUTHOR(s)	8. CONTRACT OR GRANT NUMBER(s): DAAA22-85-C-0213
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Emerson Electric Company Electronics and Space Division St. Louis, MO 63136	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS: US Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000	12. REPORT DATE: October 1987 13. NUMBER OF PAGES: 83
14. MONITORING AGENCY NAME & ADDRESS *(if different from Controlling Office)*: US Army ARDEC Benet Laboratories, SMCAR-CCB-TL Watervliet, NY 12189-4050	15. SECURITY CLASS. *(of this report)*: UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Distribution limited to Department of Defense and Department of Defense Contractors because of critical technology; October 1987. Other requests for this document must be referred to Commander, US Army Armament Research, Development, and Engineering Center, ATTN: Benet Laboratories, SMCAR-CCB-DS, Watervliet, NY 12189-4050.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

Donald E. Jones - Benet Laboratories Project Engineer

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Technology Demonstrator	Control System
Robotics	Manual Backup
Autoloader	Rearm
Ammunition Packaging	Resupply
Chain Rammer	

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

This is Phase II of a technology demonstration program for the Generic Ammunition Loading System (GALS). The work done by Emerson Electric Company in converting a conceptual design to a breadboard demonstrator is presented. A potential future ammunition resupply/rearm scheme was synthesized, and advanced technologies were applied to ammunition packaging and autoloader elements to demonstrate the application for a main battle tank.

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20. ABSTRACT (CONT'D)

Commercially available electro-hydraulically actuated mechanisms and a programmable logic controller were applied to the breadboard. Testing of the demonstrator was performed.

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: ARCCB-CR-87026	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): GENERIC AMMUNITION LOADING SYSTEM (GALS) FINAL REPORT - PHASE II	5. TYPE OF REPORT & PERIOD COVERED: Final Report - Phase II March 1986 - April 1987
6. PERFORMING ORG. REPORT NUMBER: E-2951	
7. AUTHOR(s): M. W. Osborne, S. J. Kelly, R. A. Dahl, R. D. Diseth, R. C. Schmidt, S. C. Reed, D. Frandson, T. O'Connell	8. CONTRACT OR GRANT NUMBER(s): DAAA22-85-C-0207
9. PERFORMING ORGANIZATION NAME AND ADDRESS: FMC Corporation, Northern Ordnance Division, 4800 East River Road, Minneapolis, MN 55421	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS: US Army ARDEC, Close Combat Armaments Center, Picatinny Arsenal, NJ 07806-5000	12. REPORT DATE: October 1987 13. NUMBER OF PAGES: 277
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): US Army ARDEC, Benet Laboratories, SMCAR-CCB-TL, Watervliet, NY 12189-4050	15. SECURITY CLASS. (of this report): UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Distribution limited to Department of Defense and Department of Defense Contractors because of critical technology; October 1987. Other requests for this document must be referred to Commander, US Army Armament Research, Development, and Engineering Center, ATTN: Benet Laboratories, SMCAR-CCB-DS, Watervliet, NY 12189-4050.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Donald E. Jones - Benet Laboratories Project Engineer

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Technology Demonstrator	Control System
Robotics	Manual Backup
Autoloader	Rearm
Ammunition Packaging	Resupply
Chain Rammer	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This is Phase II of a technology demonstration program for the Generic Ammunition Loading System (GALS). The work done by FMC, Northern Ordnance Division, in converting a conceptual design to a breadboard demonstrator is presented. A potential future ammunition resupply/rearm scheme was synthesized, and advanced technologies were applied to ammunition packaging and autoloader elements to demonstrate the application for a main battle tank.

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20. ABSTRACT (CONT'D)

High energy-density electric motors were applied and custom robotic transfer mechanisms were developed. Testing of the demonstrator was performed.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARCCB-TR-87027	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) EFFECT OF ROTATION ON THE LATERAL STABILITY OF A FREE-FLYING COLUMN SUBJECTED TO AN AXIAL THRUST WITH DIRECTIONAL CONTROL		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) J. D. Vasilakis and J. J. Wu (See Reverse)		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC Benet Laboratories, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6126.23.1BL0.0 PRON No. 1A-7-7Z76A-NMSC
11. CONTROLLING OFFICE NAME AND ADDRESS US Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000		12. REPORT DATE October 1987 13. NUMBER OF PAGES 15
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Presented at the Fourth Army Conference on Applied Mathematics and Computing, Cornell University, Ithaca, New York, 27-30 May 1986.
Published in Proceedings of the Conference.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Free-Flying Column
Stability
Finite Elements
Rotation
Axial Thrust

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report discusses some aspects of the stability problems of a free-flying column subjected to axial thrusts. In an age of spacecrafts and missiles, the stability of unsupported flying structures is obviously of great importance. Surprisingly though, there has not been a great deal of work addressing this type of problem. In this report, first the brief history of the lateral stability of a column is reviewed, and then the basic characteristic features of the stability problem of a free-free column are described. The mathematical
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7. AUTHORS (CONT'D)

J. J. Wu
U.S. Army European Research Office
London, England

20. ABSTRACT (CONT'D)

techniques developed to solve these problems depend on a particular problem considered. The most general case requires the solution of a nonself-adjoint differential equation/boundary condition system, which is homogeneous and with zero eigenvalues. Numerical procedures for such a system appear to work well, although theoretical proof of convergence is still lacking. Results of these procedures are discussed.

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARCCB-TR-87028	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* TRAVELLING WAVE RESONANCE IN GUN TUBES		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR*(s)* T. E. Simkins		8. CONTRACT OR GRANT NUMBER*(s)*
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC Benet Laboratories, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6111.02.H610.0 PRON No. 1A7AZ703NMSC
11. CONTROLLING OFFICE NAME AND ADDRESS US Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000		12. REPORT DATE October 1987 13. NUMBER OF PAGES 18
14. MONITORING AGENCY NAME & ADDRESS*(if different from Controlling Office)*		15. SECURITY CLASS. *(of this report)* UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

Presented at the Tenth International Symposium on Ballistics, San Diego, CA, 27-29 October 1987.
Published in Proceedings of the Symposium.

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Axially Symmetric Stress Waves in Cylinders
Axially Symmetric Motion of Cylinders
Axially Symmetric Motion of Cylindrical Shells
Resonance
Flexural Waves
Moving Pressure

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

Experimental and analytical studies have verified the existence of high amplitude dynamic strains in large caliber gun tubes. These strains have been observed to travel with the projectile as axially symmetric waves and are large enough to exceed the yield stress of the gun tube material and become even larger as the wave reflects from the muzzle. The possibility for such waves in cylinders has been known since 1964 and physical evidence for their existence in gun tubes was first reported in 1978 and in 1986 by the
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20. ABSTRACT (CONT'D)

author. These waves not only create strains higher than those for which the gun tube is designed, but are capable through coupling of producing beam-like motions affecting projectile launch conditions. Muzzle motions affecting round accuracy have long been suspect and their spurious character has evaded the most arduous attempts to predict them.

The existence of large amplitude dynamic strains in gun tubes implies a projectile environment more hostile than previously supposed. Designers of projectile casings, warheads, fuzes, etc., should be interested in these ramifications as should those concerned with projectile/tube friction and wear.

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARCCB-TR-87029	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) EVALUATION OF FILAMENT-REINFORCED ELECTROCOMPOSITES (REINFORCEMENT OF ELECTROFORMS WITH CONTINUOUS FILAMENTS)		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) V. P. Greco		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC Benet Laboratories, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6658.01.M420.012 PRON No. A1620307A11A
11. CONTROLLING OFFICE NAME AND ADDRESS US Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000		12. REPORT DATE October 1987 13. NUMBER OF PAGES 28
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Presented at the Thirty-First International SAMPE Symposium,
Las Vegas, Nevada, 7-10 April 1986.
Published in Proceedings of the Symposium.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Metal Matrix Composites
Fibrous Composites
High Strength Electrodeposited Coatings
Fiber Encapsulation

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

From a review of the literature, an updated evaluation of filament-reinforced electrocomposites is given and the benefits and limitations of the process are summarized. The successful results and properties obtained with electrocomposites from earlier studies are also presented and problems encountered are discussed. Process changes for improving the quality and strength of electrocomposites are proposed.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARCCB-TR-87030	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) HYDROGEN EMBRITTLEMENT OF GUN STEEL		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Gerald L. Spencer		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC Benet Laboratories, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 3111CT120 PRON No. 4A6CAV0202M71A
11. CONTROLLING OFFICE NAME AND ADDRESS US Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000		12. REPORT DATE November 1987 13. NUMBER OF PAGES 73
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

This was a thesis in partial fulfillment of the requirements for degree of Master of Engineering at Rensselaer Polytechnic Institute, Troy, New York.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Hydrogen Embrittlement
Notched Tensile Testing
Hydrogen Analysis
Cadmium Plating

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The objectives of this engineering project were to determine the critical concentration of hydrogen at which gun steel is embrittled, and to evaluate the effects of some acid solutions on gun steel to determine safe exposure parameters.

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20. ABSTRACT (CONT'D)

Specimens were taken from gun steel which is very similar to ASTM A723-grade 2- class 4 with a yield strength of 165 Ksi in the quenched and tempered condition. Notched tensile bars were charged with hydrogen by electrolysis. After charging, the specimens were plated with cadmium to a thickness of 0.36 mil to provide a barrier coating which would retard the loss of hydrogen. After pl-- ıg, the specimens were given a heat treatment at 300°F for 35 minutes to homogenize the sharp gradient of hydrogen within the specimen.

Notched tensile tests were conducted at room temperature and at a slow strain rate, 0.00026/min, to detect hydrogen embrittlement. With a specimen charged for 16 hours, the Notched Tensile Strength (NTS) was 97.0 percent of the original NTS and the fracture did not show embrittlement. Two specimens with a 20-hour charging time were tested with 68 percent and 77 percent of the original NTS and the fractures clearly were embrittled. Scanning electron microscopic photographs of the fractured surface verified intergranular fracture typical of hydrogen embrittlement. Hydrogen analysis was conducted on a LECO HW-100 hydrogen analyzer and diffusible hydrogen was extracted at 200°C. Hydrogen was measured for five specimens charged for 16 hours and the mean value for the critical concentration for hydrogen was 1.71 ml/100g or 1.53 ppm. Using a pickling solution of 50 percent hydrochloric acid in corrosion tests at room temperature, it was determined that it would take approximately 110 hours for the hydrogen concentration to reach the critical concentration of 1.7 ml/100g (1.5 ppm) for this gun steel.

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: ARCCB-TR-87031	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): STRUCTURAL INTEGRITY OF METALLIC ARMATURE RAIL GUNS	5. TYPE OF REPORT & PERIOD COVERED: Final
6. PERFORMING ORG. REPORT NUMBER	
7. AUTHOR(s): G.P. O'Hara and M. Cascio	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: US Army APDEC, Benet Laboratories, SMCAR-CCB-TL, Watervliet, NY 12189-4050	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: AMCMS No. 6126231BL, PRON No. D07C405707D01A
11. CONTROLLING OFFICE NAME AND ADDRESS: US Army ARDEC, Close Combat Armaments Center, Picatinny Arsenal, NJ 07806-5000	12. REPORT DATE: November 1987
	13. NUMBER OF PAGES: 21
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Presented at the Fifth U.S. Army Symposium on Gun Dynamics, The Institute on Man and Science, Rensselaerville, New York, 23-25 September 1987. Published in Proceedings of the Symposium.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Rail gun
Electromagnetic
Launcher
Composite
Structure

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The design of a rail system for an electromagnetic gun becomes more complicated when the transfer from a laboratory to a tactical system is considered. In the laboratory, weight and volume are not important and the system must be bolted together in order to be disassembled for study, modification, and repair. The tactical system must be of reasonable weight and volume, self-supporting, safe to use, have a long life, and be factory assembled. This set of design requirements must be reconciled with the function as a projectile

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20. ABSTRACT (CONT'D)

guide and an electrical conductor. The first crude prototype 'barrel' must be manufactured from available materials which do not have the optimum properties. The design then becomes a series of compromises which are performed in the hope of a successful result.

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: ARCCB-CR-87032	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): STUDY OF HIGH MODULUS GRAPHITE/HIGH TEMPERATURE POLYMERIC MATRICES - PHASE 2	5. TYPE OF REPORT & PERIOD COVERED: Final Report - Phase 2, 1 Aug 85 - 31 Jul 86
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): S. J. Calabrese, J. D. Cogdell, S. F. Murray, and H. Vollmer	8. CONTRACT OR GRANT NUMBER(s): DAAA22-84-C-0211
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Rensselaer Polytechnic Institute, Troy, NY 12180-3590	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS: US Army ARDEC, Close Combat Armaments Center, Picatinny Arsenal, NJ 07806-5000	12. REPORT DATE: November 1987
	13. NUMBER OF PAGES: 76
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): US Army ARDEC, Benet Laboratories, SMCAR-CCB-TL, Watervliet, NY 12189-4050	15. SECURITY CLASS. (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Distribution limited to US Government Agencies and their contractors only because of critical technology; November 1987. Other requests for this document must be referred to Commander, US Army Armament Research, Development, and Engineering Center, ATTN: Benet Laboratories, SMCAR-CCB-RT, Watervliet, New York 12189-4050.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Glenn S. Friar - Benet Laboratories Project Engineer

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Resin Matrix Composites	Adhesive Bonding
Graphite Fiber-Reinforced Composites	Polyimides
High Temperature Composites	Bismaleimides
Surface Preparation	Fabrication Techniques

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The objective of this work is to select candidate high temperature resins and develop fabrication techniques for making concentric, graphite fiber-reinforced composite tubes, bonded to the outside diameter of steel tubes. The purpose of the composite overlay is to strengthen and stiffen the steel tubes up to temperatures of at least 500°F.

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20. ABSTRACT (CONT'D)

dependent loads.

In the Uniform Segment Method the spatial domain is divided into a finite number of prismatic sections within which the Euler equation is applied. Solutions to this equation yield functional relationships for mode shapes in the form of trigonometric and hyperbolic functions. The overall structure is modelled as a free-free beam with intersegment continuity assured by the matching of displacement, slope, moment, and shear transfer at segment boundaries. Applying the free-free boundary and continuity conditions results in a system of equations in the unknown frequencies and coefficients. The solution of this system yields the natural frequencies and mode shape coefficients within an arbitrary constant.

The main advantage of using this method over finite elements lies in the reduced number of degrees of freedom needed to model the structure. Real prismatic sections model one to one. This is not the case in finite element methods. Additionally, a number of the transient loads known to drive gun vibrations are functions of the mode shape derivatives. Since these functions are represented analytically, which is a characteristic of the Uniform Segment Method, the need to calculate derivatives by numerical algorithms is eliminated. Thus, exactness in derivative calculations is assured.

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARCCB-TR-87033	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* NORMAL MODES ANALYSIS OF GUN VIBRATIONS BY THE UNIFORM SEGMENT METHOD		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Ronald G. Gast		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC Benet Laboratories, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6126.23.1BL0.011 PRON No. A1720518A11A
11. CONTROLLING OFFICE NAME AND ADDRESS US Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000		12. REPORT DATE November 1987 13. NUMBER OF PAGES 34
14. MONITORING AGENCY NAME & ADDRESS*(if different from Controlling Office)*		15. SECURITY CLASS. *(of this report)* UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

Presented at the Fifth U.S. Army Symposium on Gun Dynamics, The Institute on Man and Science, Rensselaerville, New York, 23-25 September 1987. Published in Proceedings of the Symposium.

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Vibrations	Elastic Supports
Modal Analysis	Numerical Methods
Beams	Gun Dynamics
Nonuniform Beams	Structural Dynamics

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

In a related paper published in the Proceedings of the Fourth US Army Symposium on Gun Dynamics (Sneck and Gast, "Normal Modes Analysis of Gun Dynamics"), the Euler-Bernoulli equation for a prismatic gun/beam elastically supported (transverse and rotation) at the breech was solved for its normal vibration modes and response to various transient loadings. This report is an extension of the reference in that the axially varying tube properties are now considered, whereas the boundary conditions are removed and applied as external displacement

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20. ABSTRACT (CONT'D)

dependent loads.

In the Uniform Segment Method the spatial domain is divided into a finite number of prismatic sections within which the Euler equation is applied. Solutions to this equation yield functional relationships for mode shapes in the form of trigonometric and hyperbolic functions. The overall structure is modelled as a free-free beam with intersegment continuity assured by the matching of displacement, slope, moment, and shear transfer at segment boundaries. Applying the free-free boundary and continuity conditions results in a system of equations in the unknown frequencies and coefficients. The solution of this system yields the natural frequencies and mode shape coefficients within an arbitrary constant.

The main advantage of using this method over finite elements lies in the reduced number of degrees of freedom needed to model the structure. Real prismatic sections model one to one. This is not the case in finite element methods. Additionally, a number of the transient loads known to drive gun vibrations are functions of the mode shape derivatives. Since these functions are represented analytically, which is a characteristic of the Uniform Segment Method, the need to calculate derivatives by numerical algorithms is eliminated. Thus, exactness in derivative calculations is assured.

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARCCB-TR-87034	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) DETERMINATION OF AQUO-COMPLEXES OF CHROMIUM AND IRON IN CHROMIUM PLATING AND POLISHING SOLUTIONS BY ION CHROMATOGRAPHY		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Samuel Sopok		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC Benet Laboratories, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6126231BL PRON No. M77F000901M71A
11. CONTROLLING OFFICE NAME AND ADDRESS US Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000		12. REPORT DATE November 1987 13. NUMBER OF PAGES 7
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Submitted to LC-GC Magazine of Liquid and Gas Chromatography.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Aquo-complexes
Chromium
Iron
Chromium Plating Solutions
Polishing Solutions
Ion Chromatography

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Aquo-complexes of chromium and iron in chromium plating and polishing solutions of individual concentration levels above 7.5 g/ℓ result in a poor quality plate condition. An ion chromatographic procedure utilizing UV-visible and atomic absorption detection for determining 0-20 g/ℓ concentration levels of these aquo-complexes is described. Since no derivatizations are necessary, matrix effects are much less common compared to previous chromatographic methods. The relative standard deviation is about two percent and sensitivity is about 1 ppm for these determinations.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARCCB-TR-87035	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) RAIL DAMAGE IN A SOLID ARMATURE RAIL GUN		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Theresa Brassard and Clarke G. Homan (See Reverse)		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC Benet Laboratories, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 611102H61 PRON No. A172026502A11A
11. CONTROLLING OFFICE NAME AND ADDRESS US Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000		12. REPORT DATE December 1987 13. NUMBER OF PAGES 17
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Presented at the Fifth U.S. Army Symposium on Gun Dynamics, The Institute on Man and Science, Rensselaerville, New York, 23-25 September 1987. Published in Proceedings of the Symposium.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Rail Guns
Solid Armature
Rail Damage

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Two types of rail guns are currently under investigation to meet Army tactical missions. Plasma arc drive rail guns operate by forming a high temperature plasma behind the projectile using a thin metal fuze. These systems achieve the highest projectile velocities (~ 12 km/sec), since the driving force includes a substantial plasma pressure as well as the electromagnetic or Lorentz force. Unfortunately, severe rail damage occurs primarily

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

7. AUTHORS (CONT'D)

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20. ABSTRACT (CONT'D)

from the intense temperatures generated by the plasma arc and the wiping motion of the armature itself. This severe rail damage is not compatible with Army tactical missions requiring multi-shot applications. The plasma armature gun will not be discussed in this report.

The solid armature gun replaces the plasma armature with a conducting metal armature. Since the plasma arcing is reduced or eliminated, the projectiles are accelerated mainly by the Lorentz force. Thus, solid armature rail guns operate at lower projectile velocities. The important tradeoff is that there is a substantial reduction in rail damage for metal armature projectiles.

Several factors limit projectile velocities in the metal armature rail guns. The most obvious is the elimination of the plasma force. However, a more subtle limit is the speed at which the commutation process can take place. Although the latter limit is still not well understood, experimental evidence indicates a commutation limit may occur near 6 to 7 km/sec. This velocity limit is still attractive for Army tactical missions for rail guns.

The actual rail damage occurring with two types of metal armatures, wire brush contactors and monolithic metal contactors, and new developments in barrel technology, such as superconducting augmentation, are presented in this report.

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARCCB-MR-87036	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* LAUNCHABILITY OF BASE-DRIVEN ELECTROMAGNETIC PROJECTILES		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) C. G. Homan and P. M. Vottis		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC Benet Laboratories, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 611102H61 PRON No. A172026502A11A
11. CONTROLLING OFFICE NAME AND ADDRESS US Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000		12. REPORT DATE December 1987 13. NUMBER OF PAGES 14
14. MONITORING AGENCY NAME & ADDRESS*(if different from Controlling Office)*		15. SECURITY CLASS. *(of this report)* UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Electromagnetic Launch
EM Projectile Launch
EM Projectile Stresses

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

The launchability of penetrator projectiles at the velocities attainable in electromagnetic (EM) launch is examined. By assuming a base-driven model, theoretical expressions are derived for the ratio of projectile mass to the mass of the penetrator core (M_T/M_p) as a function of the ratio (λ) of the length of the penetrator (ℓ) to the unsupported length of the penetrator (ℓ_0). This analysis relates the specific strengths and densities of the penetrator and sabot materials to λ and M_T/M_p.

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20. ABSTRACT (CONT'D)

It is shown that an electromagnetic projectile made from materials used in fielded penetrators and launched with a maximum acceleration of 150,000 G's can have an unsupported length (ℓ_0) of 5 to 7.2 cm dependent on the material yield criteria used. Using conservative design criteria similar to those used in the XM829 round, we show that a projectile of 2 kg mass having a 1 kg penetrator core may be launched in the base-driven mode without exceeding material properties.

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARCCB-TR-87037	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* A POSTERIORI ERROR ESTIMATION IN A FINITE ELEMENT METHOD FOR PARABOLIC PARTIAL DIFFERENTIAL EQUATIONS		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) J. M. Coyle and J. E. Flaherty (See Reverse)		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC Benet Laboratories, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6920.0R.8970.021 PRON No. 1A62ZHFCNMLC
11. CONTROLLING OFFICE NAME AND ADDRESS US Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000		12. REPORT DATE December 1987 13. NUMBER OF PAGES 23
14. MONITORING AGENCY NAME & ADDRESS(*if different from Controlling Office*)		15. SECURITY CLASS. (*of this report*) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

Presented at the Fourth Army Conference on Applied Mathematics and Computing, Cornell University, Ithaca, New York, 27-30 May 1986.
Published in Proceedings of the Conference.

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Error Estimation	Finite Element Method
Superconvergence	Backward Euler Method
Mesh Refinement	Trapezoidal Rule

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

Superconvergence properties and quadratic polynomials are used to derive a computationally inexpensive approximation to the spatial component of the error in a piecewise linear finite element method for one-dimensional parabolic partial differential equations. This technique is coupled with time integration schemes of successively higher orders to obtain an approximation of the temporal and total discretization errors. Computational results indicate that these approximations converge to the exact discretization errors as the mesh is
(CONT'D ON REVERSE)

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20. ABSTRACT (CONT'D)

refined. The approximate errors are used to control an adaptive mesh refinement strategy.

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